EVA - Evaluation of Energy Concepts: Case Study of Siedlungswerk, Stuttgart

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Abstract: This paper presents the evaluation and optimization results of the office building *Siedlungswerk* as part of the EVA project. Within EVA, 19 German office buildings are being "eva"-luated in terms of energy efficiency and user comfort.

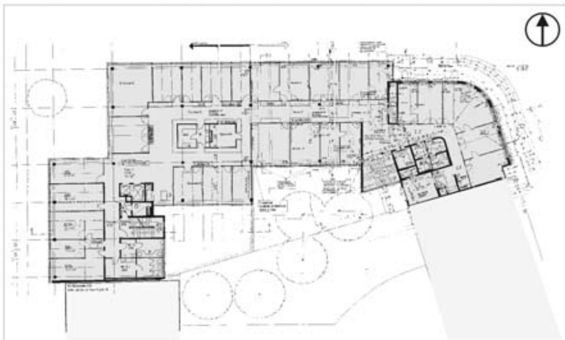
Built in the early 1990s in the city center of Stuttgart the building *Siedlungswerk* provides office spaces for 135 employees on a net heated floor area without a parking garage (NGF_r) of 5.589 m². The evaluation showed an annual consumption of primary energy of 614 kWh/(m^2_{NGFr}a). This was the highest within the *EVA* sample and significantly above reference values. Users complained about high temperatures in summer and low temperatures in winter especially during the morning hours. A short term monitoring of the indoor climate confirmed these problems. A comprehensive concept of improvement was implemented at the end of 2004 at a total cost of 250 T€ including 100 T€ for improvements in energy efficiency. The following year showed a reduction of 36 % in consumption of electrical energy and 49 % in gas consumption. The energy savings generate annual cost savings of 50 T€, which equals a return on invest in energy efficiency after two years. The optimized building operation also significantly improved the user comfort.

1. INTRODUCTION

Within the ***EVA*** project *IGS* evaluates 19 office buildings in Germany regarding energy efficiency and user comfort. The energy concepts include innovative systems and components representing state of the art building technology. The objective of *EVA* is to verify how these buildings actually perform in day-to-day operation and to identify potential improvements in operation. The EVA project is funded by the German Ministry of Economy and Technology and supported by Berliner Energie-Fond/E.ON Fond.

Built and partially retrofitted in 1992 Siedlungswerk, see Fig. 1, is the oldest building within the EVA sample. The evaluation showed a very high energy consumption and significant problems in user comfort. Therefore the owner decided to take measures to improve the buildings performance. The planning was carried out by STZ-EGS, engineering company in Stuttgart specialized on innovative building concepts and participating in the EVA project. IGS carried out a monitoring to verify the success of the improvements.

(a)



(b)

Fig. 1 Office building Siedlungswerk in the city center of Stuttgart: View from North East and ground floor plan of second floor

Fig. 2 Schemes of the heating (above) and cooling system

Fig. 3 Typical office and hall

2. BUILDING CONCEPT

The building forms part of a typical city block in Stuttgart. One half of the building has been retrofitted in 1992 and another was newly built at that time. The building was planned according to the German energy code of 1982/84 0 which requested standards for thermal insulation of the building envelope.

The building has 4 full stories, a smaller top floor and two underground levels mainly used as a parking garage. It is supplied with electrical energy as well as gas for heating and hot water. The HVAC concept is based on AHUs which are integrated in the façade. They are supplied in a change over system: the whole building is either supplied with hot or with cold water. Central heating is provided by two gas boilers with a total thermal power of 530 and 465 kW. Cooling energy is provided by three mechanical chillers of twice 120 kW_{th} and an additional 30 kW_{th}. Both systems transfer energy to the distribution system via heat exchangers arranged in row, Fig. 2.The specific installed power for heating of 178 W/m^2_{NGFr} is the highest within the EVA sample, the specific installed power for cooling of 48 W/m^2_{NGFr} is significantly above the average of 30 W/m^2_{NGFr}.

Most offices are sized for 2-4 employees. All offices have openable windows, the desks are located next to the windows, see Fig. 3. The AHUs are integrated into the façade below each window with the air intake located on the outside of the façade. The AHU supplies the rooms with heated respectively cooled air. The exhaust air is routed through a three-layer window and across a heat recovery system to the outside, see Fig. 4.

The AHUs provide the mechanical air exchange in the rooms. Thy are automatically turned off when the windows are opened in the room. Users can adjust the outside air exchange rate manually as well as the air temperature in the room (± 3K).

3. EVALUATION

The Evaluation of Siedlungswerk used energy bills to analyse the energy consumption of the previous years as well as detailed measurements of chillers and ventilation systems. The evaluation

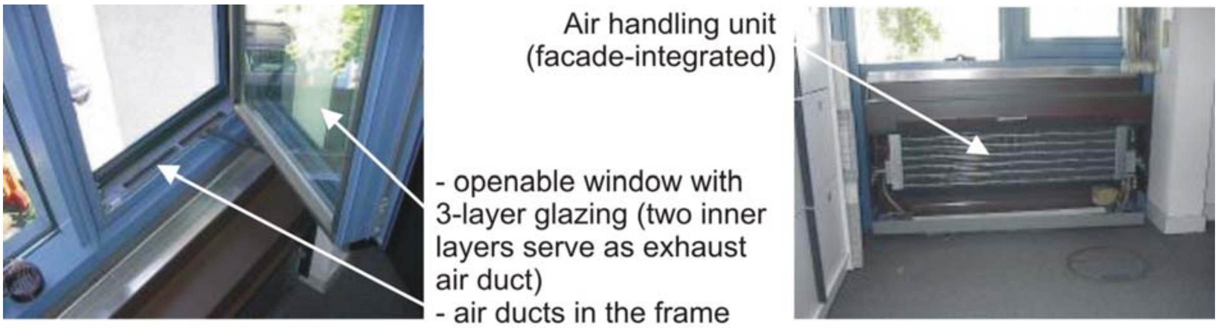


Fig. 4 Window and façade integrated air handling unit

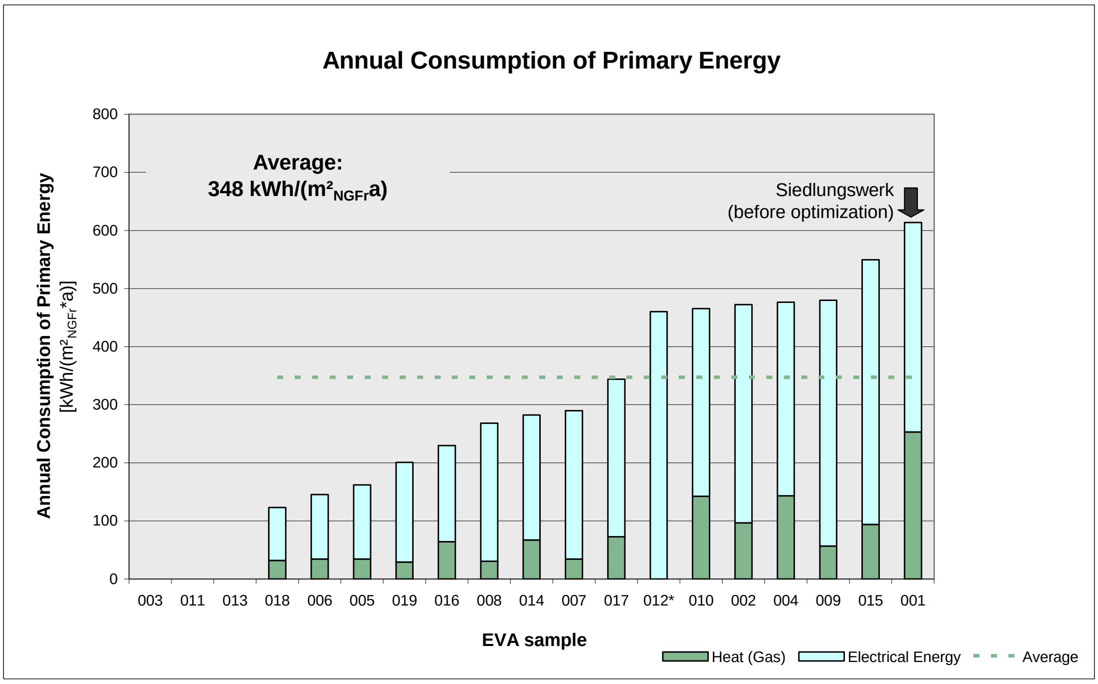


Fig. 5Annual consumption of primary energy of siedlungswerk and other EVA-buildings

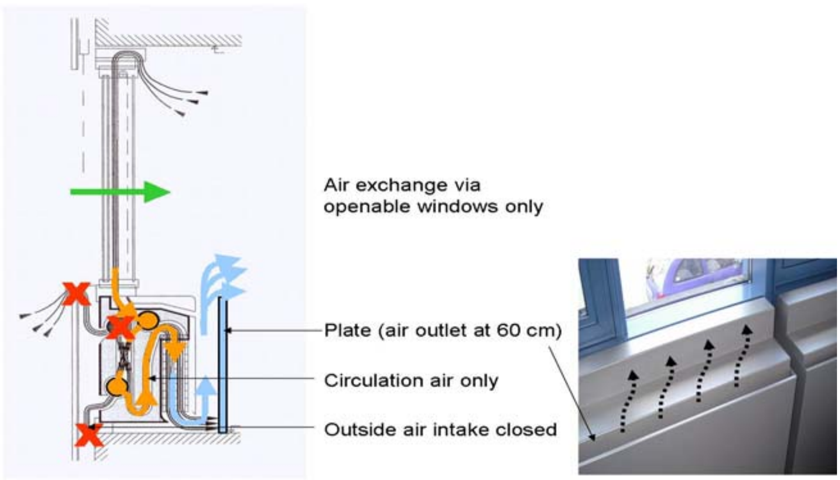


Fig. 6 Installation of plates in front of AHUs to reduce air velocity on the ground

showed an overall annual consumption of primary energy of 614 kWh/(m²NGFra), see Fig. 5.Primary energy factors: Electrical Energy: 3,0; Heat (Gas): 1,1;Data for heat consumption normalized according to VDI 3807

The final energy consumption (site consumption) of electrical energy of 120 kWh/(m²NGFra) was among the highest within the EVA study. The final energy consumption for heating (gas equivalent) of 230 kWh/(m^2_{NGFr}a) exceeded the values of all other EVA buildings and those of reference studies (0-0) of 100-140 kWh/(m^2_{NGFr}a) by far. The analysis of energy bills showed a significant gas consumption in summer.

Users complaint about high air velocities and low air temperatures in winter especially in the morning as well as about insufficient cooling in summer. Measurements confirmed these problems:

- The difference of air temperature between 0,1 m and 1,10 m measured up to 5 K (measured according to DIN EN ISO 7730 0)
- In summer the supply air was strongly heated while passing through the façade thereby reducing the cooling effect of the AHU (up to 40°C air temperature in the façade at 28 °C ambient air temperature)

The evaluation also showed several malfunctions in building operation:

- The chillers worked permanently in spring and fall, mainly to supply a single small IT-room
- The exchangers for heating and cooling supply of the AHUs were not locked against each other allowing both systems to work at the same time
- The building was heated unnecessarily in cold summer nights
- There was no night or weekend schedule in operation

4. OPTIMIZATION/RECOMMISSIONING

The owner decided to develop a concept to optimize energy efficiency and user comfort at the same time mainly by improving building operation. The concept included the following measures:

- Adjustment of the operation schedule for heating, cooling and ventilation
- Exchange of sensors of the building management system
- Installation of a small chiller for the IT-room and turning off of all other chillers most of the time in spring and fall
- Partial exchange of the existing building management system
- The operation of the AHUs was modified from supply/exhaust air to circulation air only; air exchange with the outside is now provided only by openable windows

Plates were installed in front of the AHUs to reduce high air velocity on the floor (see Fig. 6)

5. RESULTS OF OPTIMIZATION/RE-COMMISSIONING

The monitoring in EVA following theoptimization / re-commissioning of the building showed significant success. The consumption of electrical energy and gas was reduced by 36 % respectively 49 % in the first year, see Fig. 7.

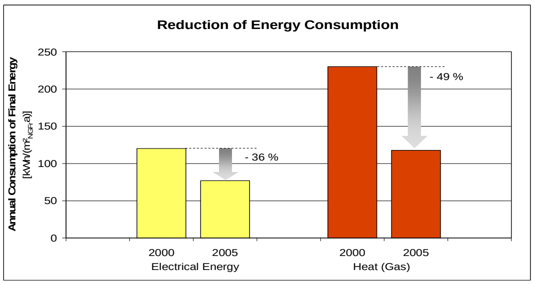


Fig. 7.Reduction of final energy consumption

Cooling now works effectively in summer reducing hours with indoor air temperatures of above 26°C (Mon-Fri, 8am-6pm) to less than 100 h/a in most rooms, far below the target value of 260 h/a according to DIN 4108 0.

6. CONCLUSION

Evaluation and optimization proofed to be very successful in this building. The annual savings in energy amount to about 50 T€/a. The investment in energy efficiency of about 100 T€ will have a

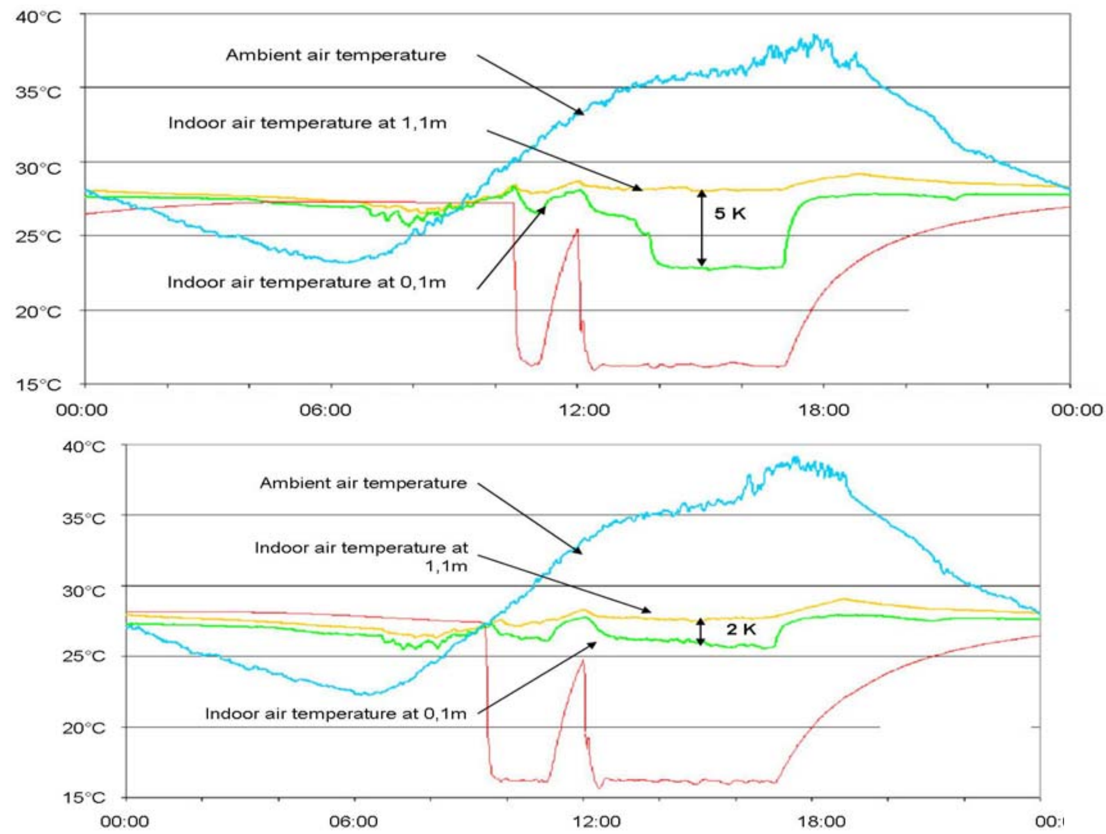


Fig. 8 Indoor air temperatures before (above) and after optimization

payback time of less than three years for the building owner.

The user comfort has been improved immediately and significantly through the investment of another 150 T€ which also included some regular retrofitting measures.

Looking at the EVA sample of buildings the strong improvement of energy efficiency and user comfort in this building might be exceptionally high. Nevertheless it demonstrates the saving potential of re-commissioning and underline the necessity for evaluation and optimization of buildings in operation.

Since façade integrated air handling units experience an increasing use in the German building sector STZ-EGS and IGS started the evaluation project DeAL. It is also funded by the German Ministry of Economy and Technology and will carry out specific analysis of these type of systems in operation.

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